Center for Satellite and Hybrid Communication Networks

Hybrid Network Control

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Industry Interest: Rockwell, GTE

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MULTI-USER DETECTION ON BOARD

(Interim Report)

- **Background**

$$x_k(t) = \sum_{i=-M_k}^{M_k} b_k(i) s_k(t - iT_k - \tau_k) \qquad k = 1,\ldots,K$$

$$r(t) = \sum_{k=1}^{K} x_k(t) + n(t) \qquad b_k(i) = \begin{cases} +1 \\ -1 \end{cases}$$

$n(t)$: WGN

- **Matched Filter Bank**

$$y_k(i) = \int_{\tau_k + iT_k}^{\tau_k + (i+1)T_k} r(t) s_k(t - iT_k - \tau_k) dt$$

MULTI-USER DETECTION ON BOARD (cont.)

- **Conventional** = $y_k(i) \underset{<}{\overset{+1}{>}} \text{Threshold}$ $\underset{-1}{}$

- **opt. MUD** = $\min_{\bar{b}} \left\| \bar{y} - R\bar{b} \right\|$ i.e. max likelihood

$$\bar{y} :< y_k(i) >$$

$$\bar{b} :< b_k(i) >$$

$$R : \langle s_m(t - nT_m - \tau_m),\ s_k(t - iT_k - \tau_k) \rangle$$

MULTI-USER DETECTION ON BOARD (cont.)

- **Sub-optimum MUD**
  - MMSE $\min E(\left\|\bar{b} - A\bar{y}\right\|^2)$
  - Decorrelator $\hat{\bar{b}} = R^{-1}\bar{y}$
  - Successive Interference Cancellation

$$< r, s_1 >= y_1 \gtrless thresh \rightarrow \hat{b}_1$$

$$y_2' = < r - \hat{b}_1 s_1, s_2 > \gtrless thresh \rightarrow \hat{b}_2$$

$$y_3' = < r - \hat{b}_1 s_1 - \hat{b}_2 s_2, s_3 > \gtrless thresh \rightarrow \hat{b}_3$$

MULTI-USER DETECTION ON BOARD (cont.)

- **Status Report**
  1. Optimum Detector: High complexity (exponential in K)
  2. Error Probability Performance: Difficult to calculate (depends on $\bar{s}_k$'s & R)

$$P_k(i) \le \sum_{\hat{\epsilon} \in \underbrace{F_k(i)}_{\text{set of indecomposable sequences}}} 2^{-w(\bar{\epsilon})} Q\left(\left\| \bar{\epsilon} \right\|_{R/\sigma} \right)$$

$$\bar{\epsilon} = \bar{b} - \hat{\bar{b}} \quad \text{error sequence}$$

  3. Other difficulties: Synchronization, energy consumption

MULTI-USER DETECTION ON BOARD (cont.)

- **Our Answers (so far)**

1. Optimum Detector <u>can</u> have polynomial complexity

   All that is needed is negative cross-correlations among the $\overline{S}_k$'s

   (*m*-sequences, Gold sequences, etc.)

   <u>AND</u> synchronism

2. Error Probability <u>can</u> be calculated

   (full characterization of indecomposable sequences)

3. Energy Consumption

   Transmission vs. Reception

   ↓ ↓

   very interesting results (read further)

   Sub-optimal MUD's have processing comparable to conventional receiver

MULTI-USER DETECTION ON BOARD (cont.)

CSHCN

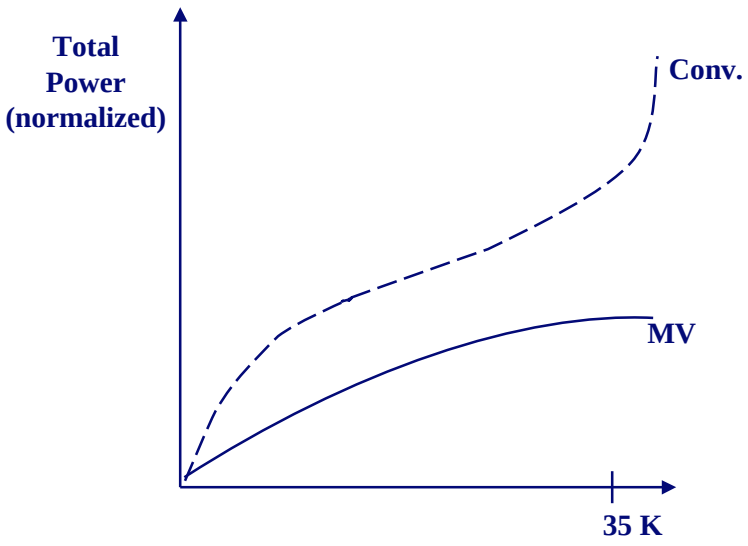
SIC

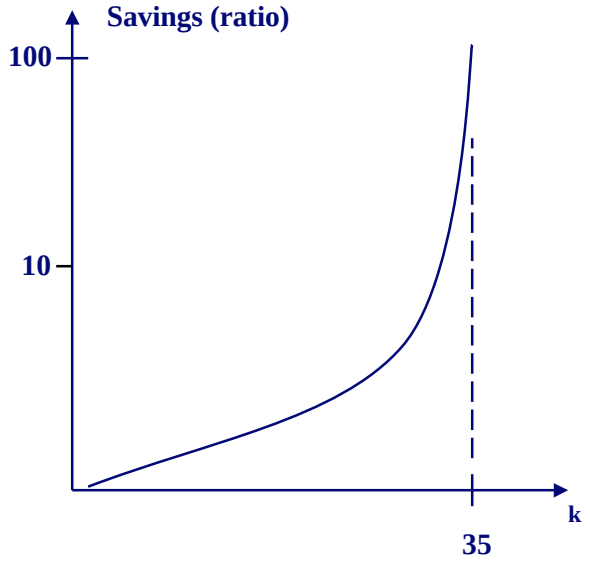
(suitable for long sequences & with minimal processing)

Some Typical Results

uniform correlation $\langle \bar{s}_m, \bar{s}_k \rangle = r = 0.002$

SINR $\gtrless$ **15**





MULTI-USER DETECTION ON BOARD (cont.)

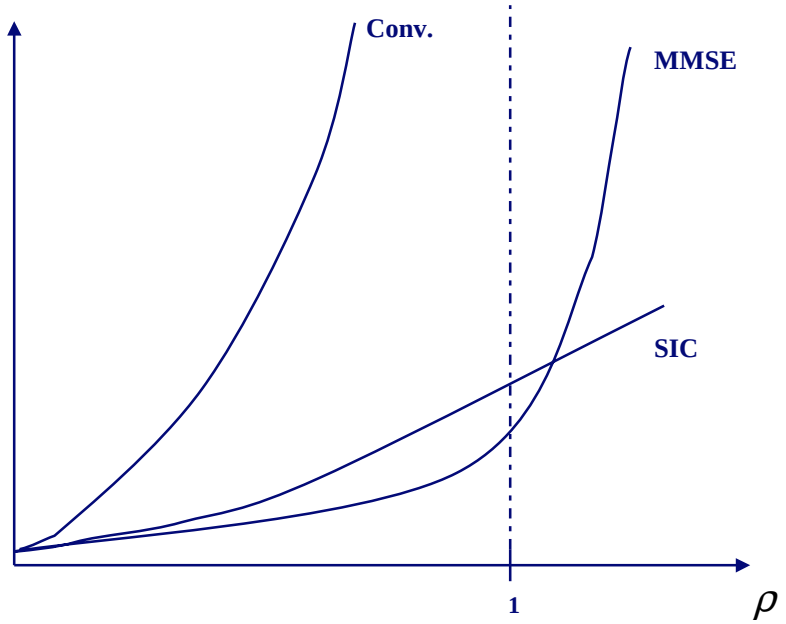
CSHCN

Power/user

L: processing gain

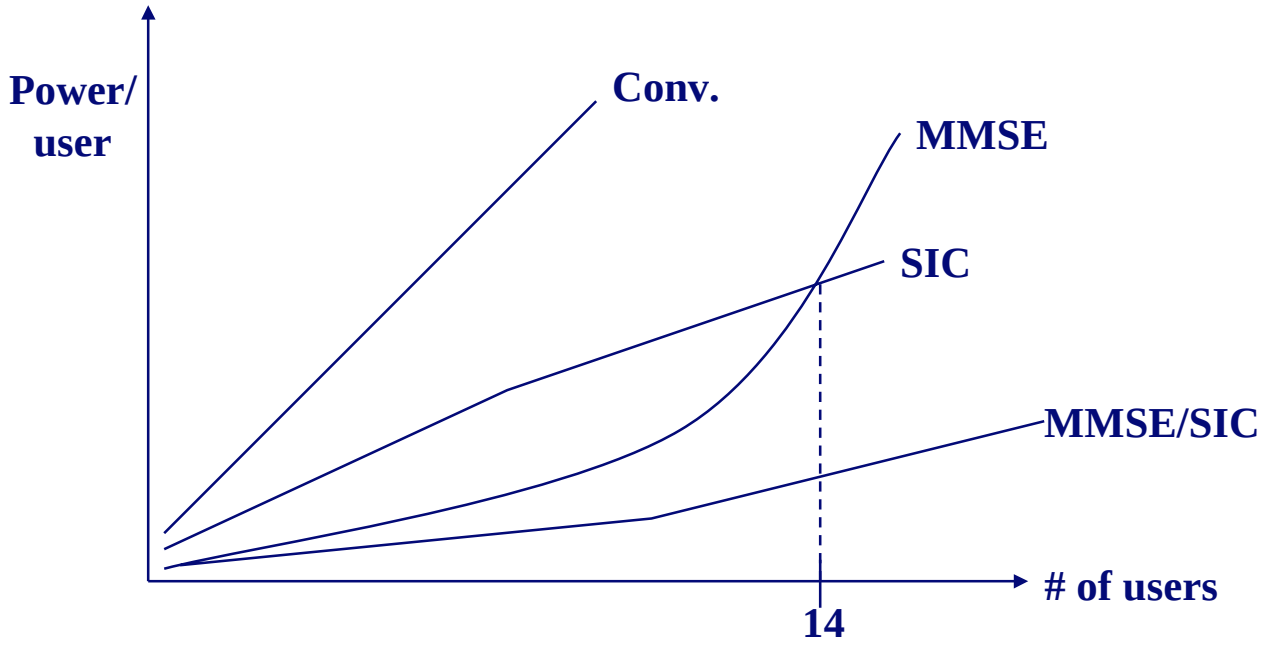
$$r = \frac{1}{L}, \quad L \to \infty, K \to \infty, \quad \rho = \frac{K}{L} = \text{constant}$$

(measure of load)



MULTI-USER DETECTION ON BOARD (cont.)

- **Simulation Result**



MULTI-USER DETECTION ON BOARD (cont.)

CSHCN

Conclusion

1. **Multi-User Detection has "cracked the nut" of multi-user communication.**
2. **Multi-User Detection is ripe for use on-board satellite**
   - complexity can be made reasonable
   - performance advantage can be calculated
   - energy savings (on the mobiles) dramatic
3. **Time to pass on to specific designs**